Class- XII
Physics

TIME ALLOWED: 3 hours **MAX MARKS:70**

General Instructions:

(i) All questions are compulsory. There are 26 questions in all

(ii) The question paper has five sections. Section A, Section B, Section C, Section D and Section E.

(iii) Section A contains five questions of one mark each, Section B contains five questions of two marks each, Section C contains twelve questions of three marks each, Section D contains one value based question of four marks and Section E contains three questions of five marks each.

(iv)There is no overall choice. However, an internal choice has been provided for one question of two marks, one question of three marks and all the three questions of five marks weightage. You have to attempt only one of the choices in such questions.

(v) You may use the following values of physical constants wherever necessary.

$c = 3\times10^8 \text{ m s}^{-1}$

$h = 6.63\times10^{-34} \text{ J s}$

$e = 1.6\times10^{-19} \text{C}$

$\mu_0 = 4\pi\times10^{-7} \text{T m A}^{-1}$

$\varepsilon_0 = 8.854\times10^{-12} \text{C}^2\text{N}^{-1}\text{m}^{-2}$

$\frac{1}{4\pi\varepsilon_0} = 9\times10^9 \text{Nm}^2\text{C}^{-2}$

$m_e = 9.1\times10^{-31} \text{kg}$

mass of neutron = 1.675×10^{-27}kg

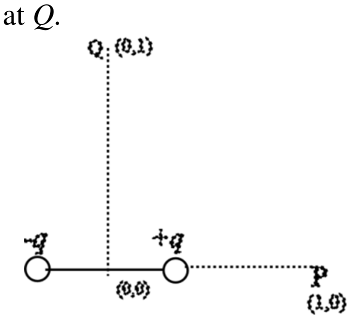
mass of proton = 1.673×10^{-27}kg

Avogadro number = 6.023×10^{23} per gram mole

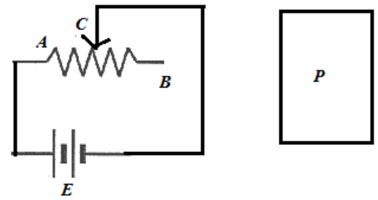
Boltzmann constant =1.38×10^{-23}JK^{-1}

SECTION A

1. An electric dipole of moment $\vec{p}$ is placed along the *x-axis* as shown. Find the ratio of the electric fields at P to that at *Q*.



2. In the circuit shown, AB is a rheostat. The terminal C of the rheostat is moved towards B. Predict the direction of current in the neighbouring coil *P* during the process.



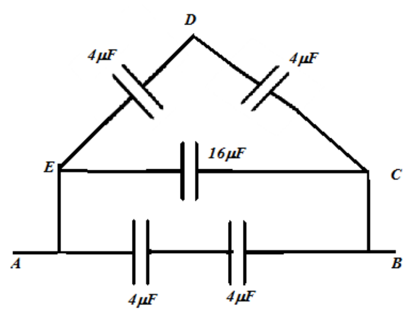
3. A capacitor is connected to a dc source. What are the magnitudes of the conduction current and the displacement current when it is fully charged?

4. Monochromatic light is incident on a glass slab of refractive index $\sqrt{3}$ and the reflected and the refracted rays are found to be perpendicular to each other. What is the angle of incidence?

5. Draw a circuit diagram for a NOR gate using NAND gates alone.

SECTION B

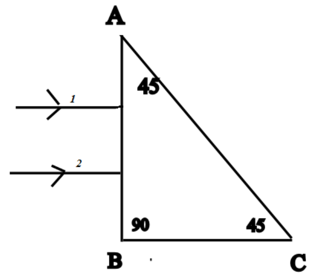
6. Find the equivalent capacitance of the combination.



If a battery of e m f 5V is applied across the terminals A and B, find the charge on the $16\mu F$ capacitor.

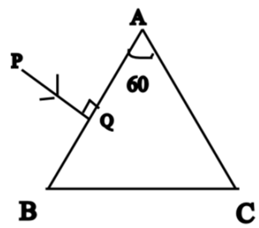
7. How are microwaves produced? Explain why microwaves are best suited for long distance transmission of signals.

8. Two monochromatic rays of light are incident normally on the face of a right angled isosceles prism ABC. The refractive indices of the glass prism for the rays 1 and 2 are 1.35 and 1.45 respectively. Trace the path of these rays after refraction through the prism.



OR

A ray PQ is incident normally on the face AB of an equilateral glass prism of refractive index $\sqrt{3}$ as shown. Trace the path of the ray after refraction through the prism.



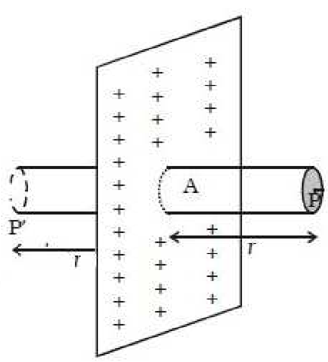
9. The de Broglie wavelength of a charged particle of mass *m* moving with a velocity *v* is λ. If the kinetic energy of the particle is reduced to $\frac{1}{4}$ of its previous value, what would be its de Broglie wavelength? Graphically represent the variation of de Broglie wavelength of a particle with its kinetic energy.

10. Calculate the wavelength of the first member and the series limit of Balmer series, given the series limit wavelength for Lyman series is 911.6 Å.

SECTION C

11. (a) State Gauss's law in electrostatics.

(b) The figure shows a cylindrical Gaussian surface for an infinitely long plane charged sheet of uniform charge density σ, placed in air.

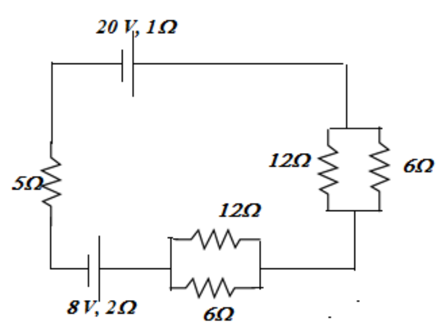


(i) Through which surface is the electric flux zero?
(ii) Over which surface is the electric field zero?
(iii) What is the ratio of the magnitudes of the electric field intensities at *P* and *P'*?
(iv) Write the expression for electric field at point *P*.

12. (a) Define the term equipotential surface. Show that the amount of work done in moving a test charge over an equipotential surface is zero.
(b) Sketch three equipotential surfaces for a positive point charge. Are these surfaces equidistant from each other? Explain.

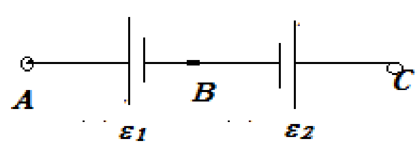
13. (a) Derive an expression for the capacitance of a parallel plate capacitor.
(b) A parallel plate capacitor with air in between the plates has a capacitance of $8\ pF$. The separation between the plates is filled with two dielectrics. One of the dielectrics has a dielectric constant $k = 4$ and a thickness of $\frac{d}{4}$, while the rest of the space between the plates is filled with a dielectric of constant $k=3$. Find the capacitance of the capacitor.

14. In the circuit shown calculate (i) the total resistance (ii) current and (iii) the terminal potential difference across the two batteries.



OR

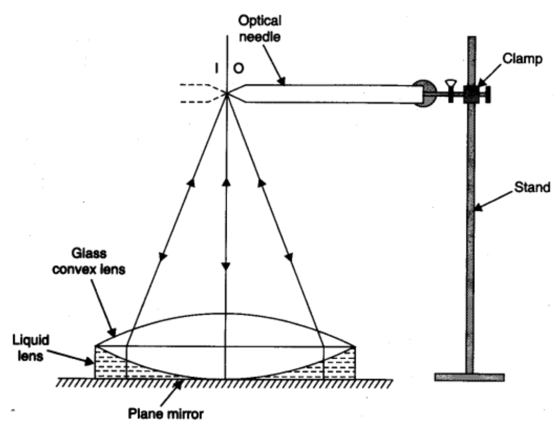
Two cells of emf ε_1 and ε_2 are connected as shown. When a potentiometer is connected between A and B, the balancing length was found to be 400 cm and when connected across A and C it was found to be 200 cm. Find the ratio of ε_1 and ε_2. If the cell ε_2 is reversed and the potentiometer is connected across A and B, what would be the balancing length?



15. A bar magnet of magnetic moment $\vec{m}$ is suspended freely in a uniform magnetic field $\vec{B}$ .At what position will the magnet come to rest? When it is rotated by an angle θ from this position and released, prove that the oscillations of the bar magnet are simple harmonic. Also deduce the time period of its oscillations.

16. A capacitor of capacitance C is connected to an alternating voltage given by $v = v_m \sin \omega t$. Find the phase relationship between the current and the voltage. Hence define capacitive reactance. Compare the behavior of the capacitor when connected to dc supply to that when connected to a c supply.

17. The figure shows a equiconvex lens of refractive index 1.5, placed over a plane mirror. A pin PQ is moved along the axis of the lens such that its tip coincides with its image. The distance between the needle and the center of the lens is measured as 30.0 cm. A few drops of liquid are added between the lens and the mirror, so that a thin layer of liquid lies between the mirror and the lens. The experiment is repeated. The new distance is measured as 45.0 cm. Find the refractive index of the liquid.



18. Two narrow slits are illuminated by a monochromatic source. What is the pattern formed on the screen called? If one of the slits is covered with a translucent sheet which lets only one fourth of the intensity of the other, what is the change in the pattern formed on the screen? If, now, one of the slits is completely covered using a black paper, what is the pattern now formed on the screen?

19. (a) what is the principle of a photocell?
(b) A photon of wavelength 1810Å falls on a plate of silver and electrons of energy 3.46×10^{-19} J are emitted. Calculate the threshold wavelength of silver.

20. State and derive the radioactive decay law. Represent the process of radioactive decay graphically. What light does the value of half-life throw on the stability of a nucleus?

21. Differentiate between intrinsic and extrinsic semiconductors. Explain how the addition of Aluminium to a silicon crystal increases its conducting properties. Draw the energy band diagram for the doped semiconductor crystal.

22. What are the different methods by which a signal wave may be modulated for long distance transmission? Diagrammatically represent (i)a signal wave (ii) its carrier wave and (iii) frequency modulated wave.

SECTION D

23. Sanjay was performing an experiment using Meter Bridge. He used a resistance box in one of the arms. Curious to know the contents of the resistance box, he opened the box to have a look. He found that the wires were doubled up and then wound into a coil. He asked why the wires were not coiled singly. The teacher told him that this winding was called non inductive winding and it helped in achieving greater accuracy due to elimination of self inductance.

(a) How do you think this winding eliminated self inductance?

(b) Why is self inductance a detriment in achieving accurate values of potential difference and resistance?

(c) What values shown by Sanjay do feel appreciating?

SECTION E

24. Explain with a neat diagram, the principle, theory and working of a Cyclotron. Also deduce an expression for the maximum kinetic energy of the accelerated ions. Graphically represent the variation of cyclotron frequency with the mass of a particle.

OR

Long distance transmission generally results in loss of energy in the form of heat. Transmission losses can be minimized if power is transmitted at a very high voltage. Explain why. What is the device used to step up the voltage of the input supply? With a neat diagram, explain its working principle. Write an expression for its efficiency. List the main causes of energy loss in the device and explain how they may be minimized.

25. (a) Draw a schematic diagram of a reflecting telescope. What are its advantages over a refracting telescope?

(b) Can a plane mirror produce real image? Explain using a diagram.

(c) A screen is placed 60 cm away from an object. The image of the object on the screen is formed by a convex lens in two different positions separated by a distance of 10 cm. Determine the focal length of the lens.

OR

(a) What is meant by resolving power of an optical instrument? Derive an expression for the resolving power of a microscope. How can the resolution of a microscope be increased?

(b) Estimate the distance for which ray optics is good approximation for an aperture of 4 mm and wavelength 400 nm?

26. (a) What is a transistor? Explain the segments of a transistor. Draw the symbols for a PNP and an NPN transistor. What is the biasing required for the transistor to be in active state?

(b) The number of silicon atoms per m^3 is 5×10^{28}. One part of Arsenic is added to the crystal per million parts of silicon. Is the resulting semiconductor N- type or P-type? Calculate the number of majority and minority charge carriers. Given $n_i = 1.5\times10^{16}\,m^{-3}$

OR

With a neat circuit diagram, explain how the characteristics of a transistor may be studied in the common emitter mode. Draw the input and the output characteristic curves and hence define (i) input resistance (ii) output resistance and (iii) current amplification factor of the transistor.

(Solution)
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Physics

SECTION A

1. Points P and Q are at the same distance from the centre of the dipole., but P is along the axial line of the dipole and Q is along the equatorial line. $E_P = \frac{2p}{4\pi\varepsilon_0 r^3}$ and $E_Q = \frac{p}{4\pi\varepsilon_0 r^3}$. Therefore, $\frac{E_P}{E_Q} = 2$

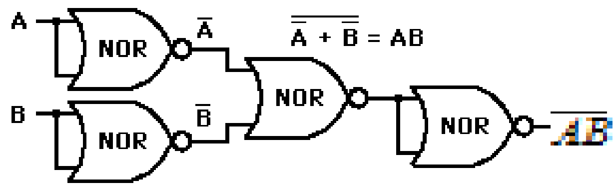
2. The current in the circuit flows in the clockwise direction. If the terminal C moves towards B, the resistance increases and the clockwise current decreases. As the current decreases, the magnetic flux through the coil P decreases. Therefore, the current in coil P flows in the anticlockwise direction.

3. When the capacitor is fully charged, its capacitive reactance becomes infinite. The conduction current is zero. The field between the plates of the capacitor is constant. Therefore the displacement current is also zero.

4. The light is incident at the polarizing angle. $\tan i_P = n$

$\tan i_P = \sqrt{3}; \boxed{i_P = 60°}$

5. The circuit for NAND gate using NOR gates alone is



SECTION B

6. The equivalent capacitance in the arm EDC is

$$\frac{1}{C_{EDC}} = \frac{1}{4} + \frac{1}{4}; C_{EDC} = 2\mu F$$

The equivalent capacitance in the arm AB is

$$\frac{1}{C_{AB}} = \frac{1}{4} + \frac{1}{4}; C_{AB} = 2\mu F$$

The total capacitance of the circuit

$C = 2+16+2 = \boxed{20\mu F}$

The charge in the 16 μF capacitor

$Q = C_{16}V = 16\times 5 = \boxed{80\mu C}$

7. Microwaves are produced by special vacuum tubes called klystrons, magnetrons or Gunn diodes. They have short wavelengths and therefore diverge less. They are suitable for radar systems used in aircraft navigation.

8. The critical angle for the ray 1 is

$$\sin i_{1c} = \frac{1}{1.35}; i_{1c} = 47.8^\circ$$

The ray 1 is incident at an angle 45^0 which is less than the critical angle.

$$\frac{\sin i_1}{\sin e_1} = \frac{1}{1.35} = 0.7407$$

$$i_1 = 45^\circ; \sin i_1 = 0.7071$$

$$\sin e_1 = 1.35\times 0.7071 = 0.9546$$

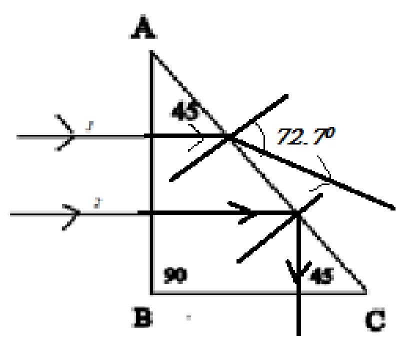
$$e_1 = 72.7^\circ$$

The ray 1 emerges at an angle 72.7^0 to the normal.

For ray 2, the critical angle is

$$\sin i_2 = \frac{1}{1.45}; i_2 = 43.6^\circ$$

The ray is incident at an angle greater than the critical angle, it is totally reflected.



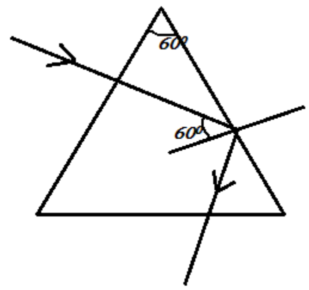
OR

The critical angle for the prism is

$$\sin i_C = \frac{1}{\sqrt{3}} = 0.5774$$

$$i_C = 35.3^\circ$$

The ray of light is incident at an angle 60^0, which is greater than the critical angle. It is totally internally reflected.



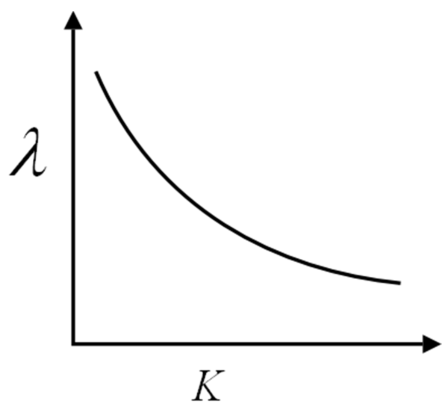
9. The debroglie wavelength of the particle is

$$\lambda = \frac{h}{\sqrt{2mK}}$$

When the kinetic energy is reduced to one fourth,

$$\lambda_1 = \frac{h}{\sqrt{2m\,K/4}} = \frac{1}{2}\frac{h}{\sqrt{2mK}} = \frac{1}{2}\lambda$$

Since $\lambda \propto \frac{1}{\sqrt{K}}$, graphically representing,



10. The wavelength of the photon emitted is given by

$$\frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

For Lyman series, the series limit is obtained when $n_1 = 1, n_2 = \infty$

$$\frac{1}{\lambda_{L\infty}} = R = \frac{1}{911.6}$$

For the Balmer series limit,

$n_1 = 2, n_2 = \infty$

$$\frac{1}{\lambda_{B\infty}} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) = \frac{1}{911.6}\left(\frac{1}{4}\right)$$

$$\boxed{\lambda_{B\infty} = 3646.4\ \overset{0}{A}}$$

For the first member,

$n_1 = 2, n_2 = 3$

$$\frac{1}{\lambda_{B1}} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) = \frac{1}{911.6}\left(\frac{1}{4} - \frac{1}{9}\right) = \frac{1}{911.6} \times \frac{5}{36}$$

$$\boxed{\lambda_{B1} = 6563.5\ \overset{0}{A}}$$

SECTION C

11. (a) Gauss's law states that, the electric flux through any closed surface is $\frac{q}{\varepsilon_0}$ where q is the total charge enclosed by the surface.

(b) (i) Electric flux is zero over the curved cylindrical surface, since $q = \oint \vec{E} \cdot d\vec{S}$ and the electric field is perpendicular to the area vector of the cylindrical surface.

(ii) Electric field is finite over all surfaces.

(iii) Points P and P' are located at the same distance from the sheet. The fields are equal at these points due to symmetry. Ratio 1:1

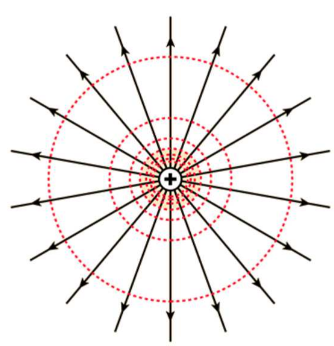
(iv) At P, $\vec{E} = \frac{\sigma}{2\varepsilon_0}\hat{n}$

12. (a) Equipotential surfaces are surfaces with a constant value of potential at all points on the surface.

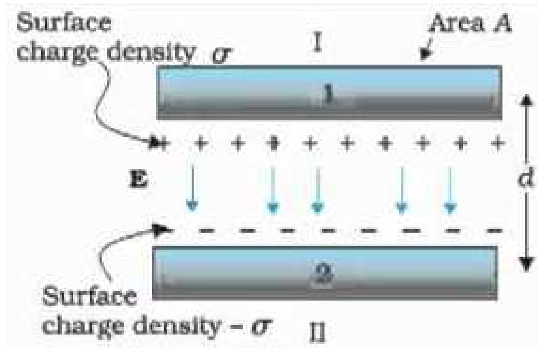
The electric field lines are normal to the surfaces. Therefore the direction of electric field lines is perpendicular to the surface. If a small displacement dl is made on the surface, the work done is given by

$W = \int \vec{E} \cdot d\vec{l} = 0$, since the angle between the directions of $\vec{E}$ and $d\vec{l}$ is 90^0.

(b) The equipotential surfaces are not equidistant from each other since electric field decreases as the distance from the charge increases. The distance between the equipotential surfaces also increases.



13. (a) A parallel plate capacitor consists of two large plane sheets of charge each of area *A* and separated by a distance *d*.



In the outer region I, above the plates, $E = \frac{\sigma}{2\varepsilon_0} - \frac{\sigma}{2\varepsilon_0} = 0$

In the region II, below the plates, $E = \frac{\sigma}{2\varepsilon_0} - \frac{\sigma}{2\varepsilon_0} = 0$

In the inner region between the plates1 and 2,

$$E = \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0} = \frac{\sigma}{\varepsilon_0} = \frac{Q}{\varepsilon_0 A}$$

The direction of the field is from the positive plate to the negative plate.

The potential difference between the plates is

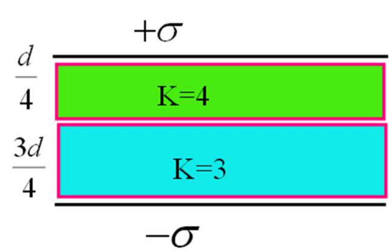
$$V = Ed = \frac{Qd}{\varepsilon_0 A}$$

The capacitance is given by

$$C = \frac{Q}{V} = \frac{\varepsilon_0 A}{d}$$

(b)The capacitance of the air-filled capacitor is $C = \frac{\varepsilon_0 A}{d} = 8\,pF$

The capacitor filled with the dielectrics is shown below. The capacitor is equivalent to two capacitors in series.



The capacitance of the capacitor with dielectric $K = 4$,

$$C_1 = \frac{4\varepsilon_0 A}{d/4} = 16C = 16 \times 8 = 128\,pF$$

The capacitance of the second part which has the dielectric $K=3$

$$C_2 = \frac{3\varepsilon_0 A}{3d/4} = 4C = 4\times 8 = 32\,pF$$

The total capacitance is

$$\frac{1}{C_K} = \frac{1}{C_1} + \frac{1}{C_2} = \frac{1}{128} + \frac{1}{32} = \frac{5}{128}$$

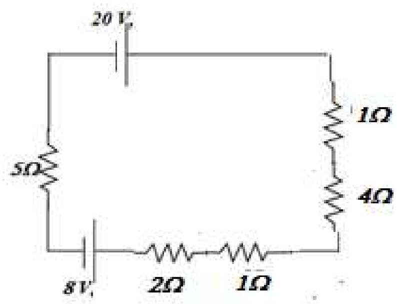
$$C_K = \frac{128}{5} = \boxed{25.6\,pF}$$

14. Since the 12Ω and the 6Ωresistances are in parallel, The equivalent resistance is

$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{12} + \frac{1}{6} = \frac{1}{4}$$

$$R_P = 4\Omega$$

The circuit is redrawn as,



The total resistance

$$R = 4+1+4+2+5 = \boxed{16\Omega}$$

The total potential difference is 20-8=12 V, since both the batteries are in opposition. The current in the circuit is

$$I = \frac{V}{R} = \frac{12}{16} = \boxed{0.75A}$$

The terminal PD across the 20 V battery is

$$V_{20} = \varepsilon - Ir_{20} = 20 - 0.75\times 1 = \boxed{19.25V}$$

The terminal PD across the 8 V battery is

$$V_8 = \varepsilon - Ir_8 = 8 - 0.75\times 2 = \boxed{6.5V}$$

OR

When the potentiometer is connected between AB

$$\varepsilon_1 \propto 400$$

When the potentiometer is connected between AC

$$\varepsilon_1 - \varepsilon_2 \propto 200$$

$$\frac{\varepsilon_1 - \varepsilon_2}{\varepsilon_1} = \frac{200}{400} = \frac{1}{2}$$

$$\boxed{\frac{\varepsilon_1}{\varepsilon_2} = 2}$$

If the cell ε_2 is reversed,

$\varepsilon_1 + \varepsilon_2 \propto l$

$$\frac{\varepsilon_1 + \varepsilon_2}{\varepsilon_1} = \frac{l}{400}; 1 + \frac{\varepsilon_2}{\varepsilon_1} = \frac{l}{400}$$

$$1 + \frac{1}{2} = \frac{l}{400}$$

$$\boxed{l = 600cm}$$

15. The bar magnet when suspended in a uniform magnetic field experiences a torque given by $\tau = mB\sin\theta$. The torque is zero when $\theta = 0$. The magnet comes to rest in the direction of the applied magnetic field.

At equilibrium, the restoring torque

$\tau = -mB\sin\theta = I\frac{d^2\theta}{dt^2}$, where, I is the moment of inertia of the bar magnet.

For small angles, $\sin\theta = \theta$

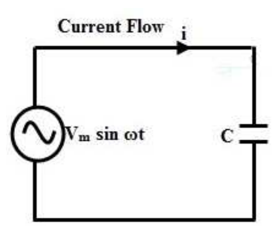
$$I\frac{d^2\theta}{dt^2} = -mB\theta$$

$$\frac{d^2\theta}{dt^2} = -\frac{mB}{I}\theta$$

This represents simple harmonic motion.

The angular frequency $\omega^2 = \frac{mB}{I}$ and the time period is $T = 2\pi\sqrt{\frac{I}{mB}}$

16. Consider a capacitor of capacitance C connected to an ac source generating a voltage $v = v_m \sin\omega t$. The capacitor is charged and then discharged alternately during each half cycle.



If q is the charge on the capacitor at any time t, the instantaneous voltage v across the capacitor is

$$v = \frac{q}{C}$$

By Kirchhoff's loop rule,

$$v_m \sin \omega t = \frac{q}{C}$$

Since the instantaneous current $i = \frac{dq}{dt}$,

$$i = \frac{d}{dt}\left(v_m \mathrm{C} \sin \omega t\right) = C\omega v_m \cos \omega t$$

$$= C\omega v_m \sin\left(\omega t + \frac{\pi}{2}\right)$$

Therefore,

$$i = i_m \sin\left(\omega t + \frac{\pi}{2}\right),$$

Where

$$i_m = C\omega v_m = \frac{v_m}{1/C\omega}$$

The term $\frac{1}{C\omega}$ plays the role of resistance in the capacitive circuit and it is called capacitive reactance X_C.

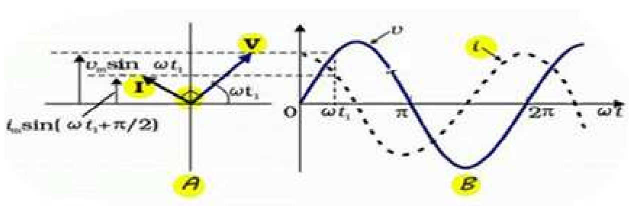
$$X_C = \frac{1}{C\omega}$$

The instantaneous current can be written as

$$i_m = \frac{v_m}{X_C}$$

From the equation $i = i_m \sin\left(\omega t + \frac{\pi}{2}\right)$, and $v = v_m \sin \omega t$ it is seen that the current in a capacitive circuit is ahead of the voltage by a phase $\frac{\pi}{2}$.

The phase relationship is described in the phasor diagram and the graph shown below.



Capacitive reactance is the opposition offered to the passage of current when a capacitor is connected in the circuit. It has the same dimensions of resistance and its SI unit is ohm.

When connected to a dc circuit, since $\omega = 0, X_C = \frac{1}{C\omega} = \frac{1}{0} = \infty$. A capacitor blocks dc after it is fully charged.

When connected to a c $X_C \propto \frac{1}{\omega}$ and $X_C \propto \frac{1}{C}$

17. The distance between the needle and the lens gives the focal length *f* of the lens.

$f = 30.0$ cm

Using lens maker's formula

$$\frac{1}{f} = (n_g - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Here, the refractive index of the lens is $n_g = 1.5$ and for equiconvex lens,

$$R_1 = R; R_2 = -R$$

$$\frac{1}{f} = (n_g - 1)\left(\frac{1}{R} - \left(-\frac{1}{R}\right)\right) = (n_g - 1)\frac{2}{R}$$

$$\frac{1}{30.0} = (1.5 - 1)\frac{2}{R}$$

$R = 30.0$ cm

In the second case the distance between the lens and the pin gives the combined focal length *F* of the convex lens and the Plano concave liquid lens f_l.

$F = 45.0$ cm

$$\frac{1}{F} = \frac{1}{f} + \frac{1}{f_l}$$

$$\frac{1}{f_l} = \frac{1}{F} - \frac{1}{f} = \frac{1}{45.0} - \frac{1}{30.0} = -\frac{1}{90.0}$$

$f_l = -90.0$ cm

Using lens maker's formula for the planoconcave liquid lens of refractive index n_l,

$$\frac{1}{f_l} = (n_l - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \text{ and } R_1 = -R; R_2 = \infty,$$

$$\frac{1}{f_l} = (n_l - 1)\left(-\frac{1}{R} - \frac{1}{\infty}\right) = (n_l - 1)\left(-\frac{1}{R}\right)$$

$$-\frac{1}{90.0} = (n_l - 1)\left(-\frac{1}{30.0}\right)$$

$$n_l - 1 = \frac{1}{3}$$

$$\boxed{n_l = \frac{4}{3}}$$

18. The pattern formed on the screen consists of alternate bright and dark bands of equal width and all the bright bands have the same intensity. The pattern is an interference band.

Intensity at any point on a screen due to two sources of intensities I_1 and I_2 is given by

$$I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$$

For constructive interference, $\cos\phi = 1$

$$I_{\max} = \left(\sqrt{I_1} + \sqrt{I_2}\right)^2$$

Since $I_1 = I_0$ and $I_2 = \frac{I_0}{4}$,

$$I_{\max} = \left(\sqrt{I_0} + \sqrt{\frac{I_0}{4}}\right)^2 = I_0\left(1 + \frac{1}{2}\right)^2 = \frac{9}{4}I_0$$

For destructive interference, $\cos\phi = -1$

$$I_{\min} = \left(\sqrt{I_1} - \sqrt{I_2}\right)^2 = \left(\sqrt{I_0} - \sqrt{\frac{I_0}{4}}\right)^2 = I_0\left(1 - \frac{1}{2}\right)^2 = \frac{1}{4}I_0$$

When one slit is completely covered the pattern changes to a single slit diffraction pattern.

19. (a) A photo cell works on the principle of photoelectric emission. When light of suitable frequency falls on a photosensitive plate, electrons are emitted. The photoelectric current is found to be proportional to the intensity of incident light.

(b) Using Einstein's photoelectric equation,

$$\frac{hc}{\lambda} = \frac{hc}{\lambda_0} + K$$

Energy of the incident light,

$$\frac{hc}{\lambda} = \frac{6.63\times10^{-34}\times3\times10^{8}}{1.810\times10^{-7}} = 11\times10^{-19}\,\text{J}$$

Threshold energy

$$\frac{hc}{\lambda_0} = \frac{hc}{\lambda} - K = 11\times10^{-19} - 3.46\times10^{-19} = 7.54\times10^{-19}\,\text{J}$$

Threshold wavelength

$$\lambda_0 = \frac{6.63\times10^{-34}\times3\times10^{8}}{7.54\times10^{-19}} = \boxed{2.638\times10^{-7}\,\text{m}}$$

20. Law of radioactive decay

The number of nuclei undergoing decay per unit time is proportional to the number of nuclei present in that sample at that instant of time.

$$-\frac{dN}{dt} \propto N$$

$$\frac{dN}{dt} = -\lambda N$$

where λ is called the *decay constant*.

$$\frac{dN}{N} = -\lambda dt$$

Integrating both sides,

$$\int_{N_0}^{N} \frac{dN}{N} = \int_{t_0}^{t} -\lambda dt$$

$$\ln N - \ln N_0 = \lambda(t_0 - t)$$

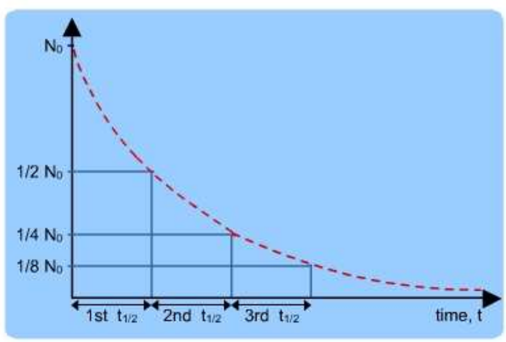
Here, the number of nuclei at $t = t_0$ is N_0. If it is set such that $t_0 = 0$,

$$\ln \frac{N}{N_0} = -\lambda t$$

$$N = N_0 e^{-\lambda t}$$

This is the radioactive disintegration law.

It is graphically represented as



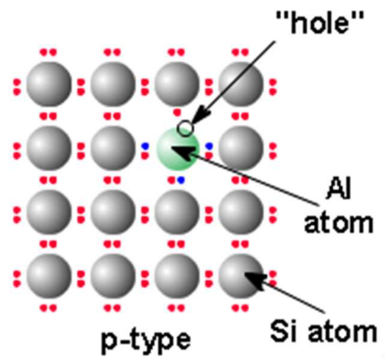
Half life of a radioactive sample is the time taken for half the nuclei to decay. Greater the value of half life, greater is the stability of the nucleus.

21. Intrinsic and extrinsic semiconductors:

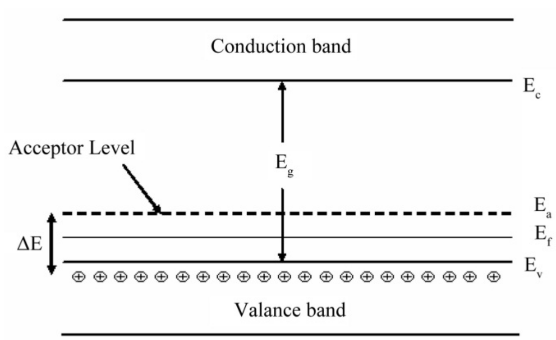
SN	Intrinsic semiconductors	Extrinsic semiconductors
1	these are pure semiconductors	These have trivalent or pentavalent impurities doped in them
2	The conductivity is low and is dependent only on temperature	High electrical conductivity and is dependent on both temperature and the concentration of the dopant.
3	The number of free electrons is equal to the number of holes	In the n- type, the number of electrons is greater than that of holes and in the type, the number of holes is greater than the

		number of electrons.
4	There are no permitted energy levels between the valence and the conduction bands.	The permitted level of the impurity atom lies in between the valence and the conduction bands.

Aluminium is a trivalent impurity. The three valence electrons form three bonds with the neighbouring silicon atoms and a vacant space is created in the bond with the fourth silicon atom. The vacancy is called *hole* , it behaves as a positive charge and it may be filled by any electron from the other atoms in the crystal. The Aluminium atom becomes negatively charged and is called *acceptor ion.* Each aluminium atom added to the crystal contributes one hole to the crystal. The majority charge carriers are holes and the semiconductor is called *p type semiconductor.*



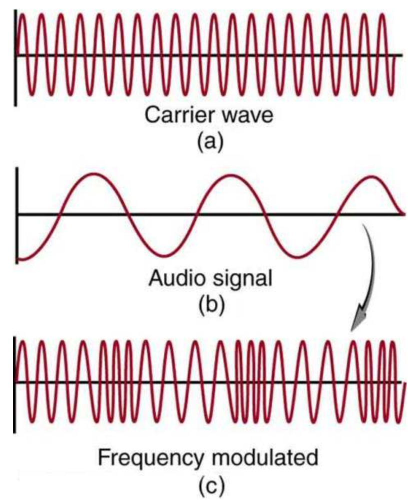
In the energy band diagram of the silicon crystal, an acceptor level is added very close to the valence band of the crystal. The electrons from the valence band are transported into the acceptor level with a very small supply of energy, leaving behind holes in the valence band.



22. The various methods of modulation are

(i) Amplitude modulation- The amplitude of the carrier wave is varied in accordance with the amplitude of the signal wave.

(ii) Frequency modulation- The frequency of the carrier wave is modulated in accordance with the amplitude of the signal wave. The amplitude of the carrier wave remains constant.
(iii) Phase modulation- The phase of the carrier wave is modulated in accordance with the amplitude of the signal wave. The amplitude of the carrier wave remains constant. The pattern of the phase modulated wave is similar to the frequency modulated but is at a phase difference of 90^0 with the frequency modulated wave.



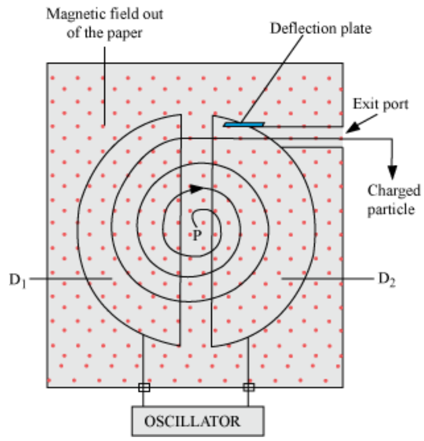
SECTION E

23. (a) When wires are doubled up and wound, they carry currents in the opposite directions at any instant of time. The magnetic fields generated by the currents are also in opposite directions and they cancel each other. Therefore, self inductance is minimized.
(b) Self inductance creates a back emf in a coil while the current varies. The total potential difference will be less than the potential difference supplied to it. Hence the measurements of potential difference will not be accurate. This in turn affects the value of current measured and therefore the value of resistance too.
(c) Scientific enquiry, quest to acquire more knowledge.

SECTION E

24. Cyclotron: Cyclotron is a device used to accelerate particles to high energies.
Principle: Cyclotron uses crossed electric and magnetic fields to increase the energy of the particle. The frequency of revolution of a charged particle in a magnetic field is independent of its energy.
Construction: Cyclotron consists of two semicircular disc like metal containers called dees which are completely evacuated. These dees are

connected to a high frequency oscillator, which provides an electric field in the space between the dees and the space inside the dees is free from the electric field due to electrostatic shielding. A strong and uniform magnetic field is acted upon the dees.



Working: A positively charged particle is placed in the space between the dees. If at the instant the dee at the right is negatively charged, the particle is attracted towards the dee. Inside the dee, it is acted upon by a constant magnetic field and it describes a circular path of radius in accordance with its speed. The frequency of the oscillator is set in such a manner that when the ion reaches the edge of the dee, the polarity of the dees reverse. The left dee becomes negatively charged and the ion is accelerated in the gap between the dees and enters the left dee. Since its velocity of entry into the magnetic field is greater, it describes a circular path of greater radius. As the sign of the electric field is changed alternately in tune with the circular motion of the particle, the particle is accelerated in the electric field and its energy increases.

Theory:

The centripetal force for the particle of charge *q*, mass *m* ,to move in a circular path of radius *r* with a velocity *v* in a magnetic field *B* is provided by the magnetic Lorentz force.

$$\frac{mv^2}{r} = qBv$$

$$\frac{v}{r} = \omega = \frac{qB}{m}$$

$$\nu = \frac{\omega}{2\pi} = \frac{qB}{2\pi m}$$

This frequency is called cyclotron frequency. The applied frequency of the external electric field is adjusted to have the same value as the cyclotron frequency to obtain resonant condition.

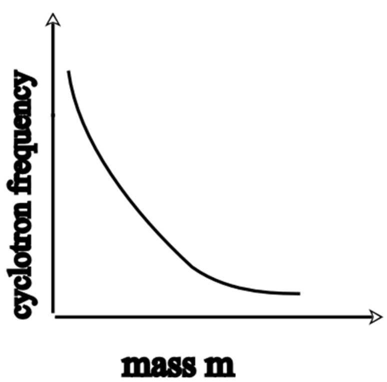
Kinetic energy: As the particle crosses the gap between the dees, it gains an energy qV where V is the potential difference between the dees. With each revolution, the ion traces a path of greater radius and when its radius is equal to the radius of the dee, it attains the maximum energy that can be imparted to it by the cyclotron.If R is the radius of the Dee, the maximum velocity of the particle is

$$v = \frac{qBR}{m}$$

The maximum kinetic energy

$$K_{\max} = \frac{1}{2}mv^2 = \frac{q^2B^2R^2}{2m}$$

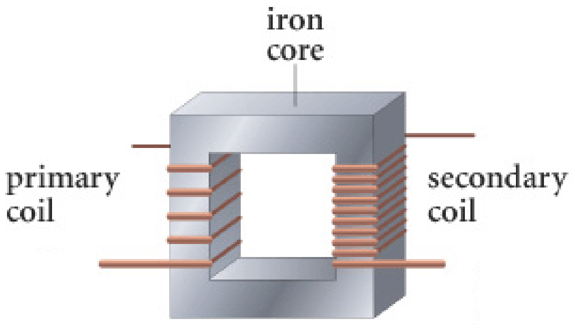
$$\nu \propto \frac{1}{m}$$



OR

The length of the wire needed depends on the distance to which power needs to be transmitted. For long distance power transmission the length of the wire is large and since resistance increases linearly with the increase in length, the value of resistance is very large. When power is transmitted at low voltages, the current is large since $P = VI$. The heat loss is I^2Rt which is also very large. But if the voltage of transmission is large, the current is small and the heat loss is also greatly reduced.

The device used to step up voltage is called a step up transformer. A transformer works on the principle of mutual induction. When an alternating voltage is applied to the primary coil of the transformer, the resulting alternating current produces a varying magnetic field. The varying magnetic field produces varying magnetic flux across the secondary coil. An e m f is induced across the secondary. The value of e m f depends on the number of turns of the coil .



In a step up transformer, the number of turns in the secondary N_s is greater than the number of turns N_p in the primary.

The voltage induced in the secondary is

$$v_s = -N_s \frac{d\phi}{dt}$$

The voltage across the primary

$$v_p = -N_p \frac{d\phi}{dt}$$

$$\frac{v_s}{v_p} = \frac{N_s}{N_p}$$

This is called transformation ratio and for step up transformer transformation ratio is greater than 1.

The efficiency of a transformer is the ratio of the output power to the input power.

$$\eta = \frac{i_s v_s}{i_p v_p}$$

Losses in transformer:

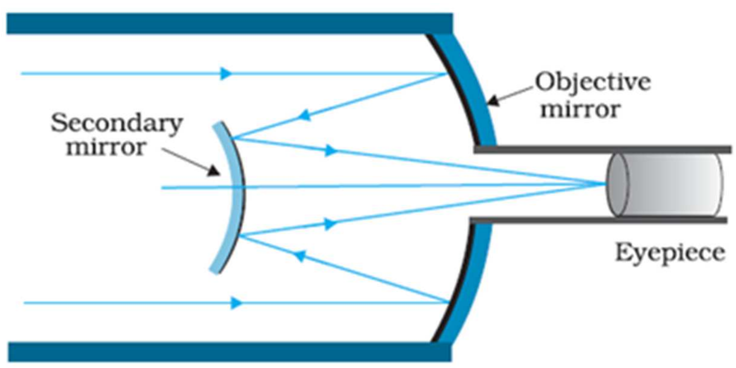
(i) Flux leakage: Not all the flux produced in the primary is linked with the secondary. This is minimised by winding the secondary coil over the primary.

(ii) Heat loss: Current in the primary and the secondary produces heat loss due to joule effect. This is minimised by choosing wires of low resistance.

(iii) Eddy currents: The varying magnetic flux produces eddy currents in the core and energy is lost as heat. This is minimised by using a laminated core.

(iv) Hysterisis loss: The repeated magnetisation and demagnetisation of the core results in energy loss due to hysteresis. This is minimised by choosing a core of magnetic material with low hysteresis loss.

25. (a) Cassegrain reflecting telescope

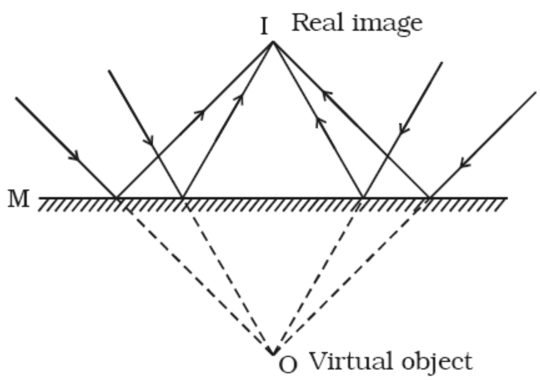


Advantages:

(i) There is no chromatic aberration in a mirror, while a lens has chromatic aberration due to refraction.

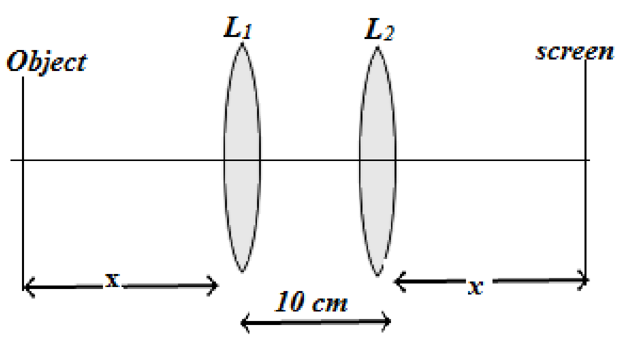
(ii) The use of parabolic mirrors eliminate spherical aberration

(b) A plane mirror can form a real image when the rays falling on the mirror are converging.



Real image in a plane mirror

(c) The two positions of the lens are the conjugate positions.



$x + 10 + x = 60cm$

$x = 25cm$

When the lens in the position L_1,

$u = -25$ cm; $v = 10 + 25 = 35$ cm

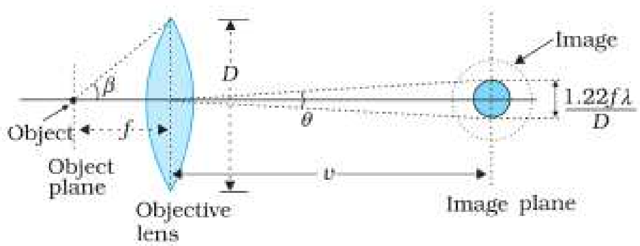
$$\frac{1}{f}=\frac{1}{v}-\frac{1}{u}$$

$$=\frac{1}{35}+\frac{1}{25}=\frac{12}{175}$$

$$\boxed{f=14.6\text{cm}}$$

OR

(a) The resolving power of a microscope is given by the reciprocal of the minimum separation of two points seen as distinct.



The object is placed beyond *f* and the real image is formed at a distance *v*.

$$\frac{D}{f}=2\tan\beta$$

Here 2 β is the angle subtended by the diameter of the objective lens at the focus of the microscope.

When the separation between two points in a microscope specimen is comparable to the wavelength λ of the light, the image of a point object will be a diffraction pattern whose size in the image plane will be

$$v\theta=v\left(\frac{1.22\lambda}{D}\right)$$

Two objects whose images are closer than this distance will not be resolved. The corresponding distance of separation of in the object plane is

$$d_{\min}=\frac{\left[v\left(\frac{1.22\lambda}{D}\right)\right]}{m},$$

Where *m* is the magnification $m=\frac{v}{f}$.

$$d_{\min}=\frac{1.22f\lambda}{D}$$

$$d_{\min}=\frac{1.22\lambda}{2\tan\beta}\approx\frac{1.22\lambda}{2\sin\beta}$$

If the medium between the object and the lens has a refractive index *n*,

$$d_{\min}=\frac{1.22\lambda}{2n\sin\beta}$$

$$\text{Resolving power} = \frac{1}{d_{\min}} = \frac{2n\sin\beta}{1.22\lambda}$$

The resolving power of a microscope can be increased by choosing a medium of higher refractive index.

(b) $z_F = \frac{a^2}{\lambda} = \frac{\left(4\times10^{-3}\right)^2}{4\times10^{-7}} = 40m$

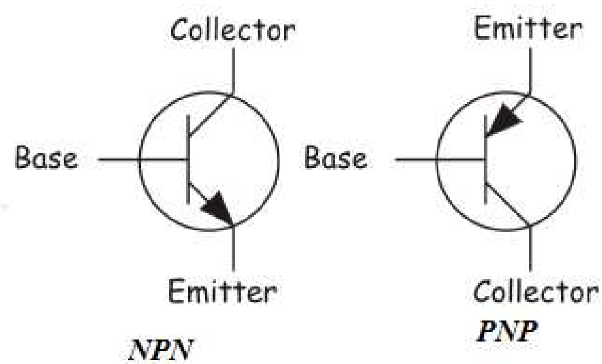
26. (a) A transistor is a device which has three doped regions forming two p-n junctions between them.

The segments of the transistor are

(i) Emitter: It is of moderate size and heavily doped. It supplies a large number of majority charge carriers for the current flow through the transistor.

(ii) Base: This is the central segment. It is very thin and lightly doped.

(iii) Collector: It is moderately doped and of larger size. This segment collects a major portion of the majority charge carriers.



For the transistor to be in active state the emitter base junction is forward biased and the collector base junction is reverse biased.

(b) Arsenic is a pentavalent impurity. The resulting semiconductor is *N* type. The majority charge carriers are electrons and the minority charge carriers are holes.

The number of dopant atoms

$$N_D = \frac{5\times10^{28}}{10^6} = 5\times10^{22}\,\text{m}^{-3}$$

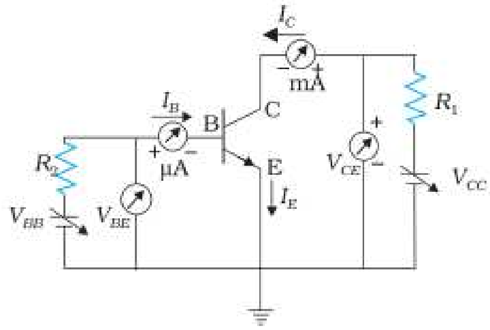
Each dopant atom contributes 1 electron to the crystal. The number of electrons is very less in the intrinsic semiconductor and is equal to

$$n_e = N_D = \boxed{5\times10^{22}\,\text{m}^{-3}}$$

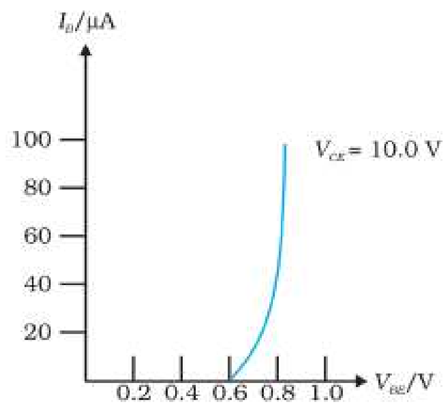
$$n_h = \frac{n_i^2}{n_e} = \frac{\left(5\times10^{16}\right)^2}{5\times10^{22}} = \boxed{4.5\times10^{9}\,\text{m}^{-3}}$$

OR

The circuit diagram to study the characteristics of an NPN transistor in CE configuration is shown below.

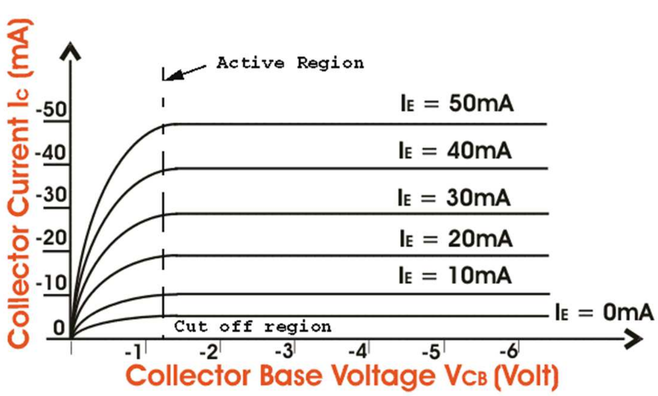


The input is applied between the base and the emitter and the output is between the collector and the emitter. The variation of the base current I_B with the base- emitter voltage V_{BE} is the input characteristic.



The collector – emitter voltage V_{CE} is kept constant and the base – emitter voltage V_{BE} is varied. The corresponding variation in the base current I_B is noted. The collector – emitter voltage V_{CE} is kept at a large value so that the transistor remains in active state. The input characteristic graph is shown above.

The variation of the collector current I_C with the Collector- emitter voltage V_{CE} at constant base current I_B is the output characteristic. When I_B increases, I_C also increases. There are different output characteristic curves corresponding to different values of I_B. the output characteristic curves are shown below.



(i) Input resistance (r_i) is the ratio of change in base- emitter voltage ΔV_{BE} to the resulting base current ΔI_B.

$$r_i = \left(\frac{\Delta V_{BE}}{\Delta I_B}\right)_{V_{CE}}$$

(ii) Output resistance is defined as the ratio of change in collector- emitter voltage ΔV_{CE} to the resulting collector current ΔI_C. At a constant valueof base current.

$$r_o = \left(\frac{\Delta V_{CE}}{\Delta I_C}\right)_{I_B}$$

(iii) Current amplification factor is the ratio of the change in collector current to the change in base current at a constant value of collector base voltage.

$$\beta = \left(\frac{\Delta I_C}{\Delta I_B}\right)_{V_{CE}}$$